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"Strain and Quantum Dots Manipulation in Nitride Compounds for Opto-electronic Devices"
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Agreement Number: W911NF0410297

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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHORS
S. M. Bedair, N. A. El-Masry

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
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8. PERFORMING ORGANIZATION REPORT NUMBER

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14. ABSTRACT
Activities during the project period can be divided into two main areas. The first dealt with quantum structure and optical properties of light sources based on GaInN/AlInGaN quantum well structures. The second area covered research in the room temperature ferromagnetic properties of GaMnN dilute magnetic semiconductors.

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Report Title

"Strain and Quantum Dots Manipulation in Nitride Compounds for Opto-electronic Devices"
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ABSTRACT

Activities during the project period can be divided into two main areas. The first dealt with quantum structure and optical properties of light sources based on GaInN/AlInGaN quantum well structures. The second area covered research in the room temperature ferromagnetic properties of GaMnN dilute magnetic semiconductors.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Number of Papers published in peer-reviewed journals: 7.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts): 5

(d) Manuscripts

Number of Manuscripts: 7.00

Number of Inventions:

Graduate Students

NAME	PERCENT_SUPPORTED
Mason Reed PhD Aug. 2005	0.50
Baxter Moody PhD Aug. 2006	0.50
Philip Barletta PhD Aug. 2006	0.50
Erdem Arkun PhD Aug. 2006	0.50
FTE Equivalent:	**2.00**
Total Number:	**4**

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
S. M. Bedair	0.02	No
N. A. El-Masry	0.02	No
FTE Equivalent:	**0.04**	
Total Number:	**2**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME	
Erdem Arkun, PhD, Aug. 2006	
Philip Barletta, PhD, Aug. 2006	
Baxter Moody, PhD, Aug. 2006	
Mason Reed, PhD, Aug. 2005	
Total Number:	**4**

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

ARO-Final Report.

Strain and Quantum Dots Manipulation in Nitride Compounds for Opto-electronic Devices

P.I.

S. M. Bedair

ECE- NC State University

Activities during the project period can be divided into two main areas. The first dealt with quantum structure and optical properties of light sources based on GaInN/AlInGaN quantum well structures. The second area covered research in the room temperature ferromagnetic properties of GaMnN dilute magnetic semiconductors.

The following are summaries and highlights of the research and published work supported by this ARO funding:

1. ***"Design of white light emitting diodes using InGaN/AlInGaN quantum well structure"*** [Applied Physics Letter 84, 672 (2004)].

D. Xiao, K. W. Kim, and S. M. Bedair
Department of Electrical and Computer Engineering, North Carolina State University, Raleigh, North Carolina 27695
J. M. Zavada
U.S. Army Research Office, Research Triangle Park, North Carolina 27709.

Abstract:

Based on the Rashba–Sheka–Pikus Hamiltonian in the vicinity of the Γ point, and taking into consideration spontaneous and piezoelectric polarization, the optical intensity of nitride-based quantum-well light-emitting diodes has been calculated. It is found that strain substantially alters the subband structure and thus the output intensity of these nitride-biased quantum-well light-emitting diodes. A design that uses AlInGaN as the quantum barrier is proposed to realize efficient red emission, which is hard to achieve if GaN is used as the barrier. In the proposed design, three different InGaN/AlInGaN quantum-well structures emit red, green, and blue light of similar intensity. Also, to achieve high efficiency, important factors related to the oscillator strength are discussed in detail.

2. “Development of green, yellow and amber light emitting diodes using InGaN multiple quantum well structure.”

[Applied Physics Letter 90, 151109 (2007)].

Philip T. Barletta, E. Acar Berkman, Baxter F. Moody, and Nadia A. El-Masry, Ahmed M. Emara, Mason J. Reed, and S. M. Bedair

Abstract:

The authors present optical and electrical data for long wavelength (573–601 nm) InGaN/GaN multiple quantum well light emitting diodes (LEDs) grown by metal organic chemical vapor deposition. These results are achieved by optimizing the active layer growth temperature and the quantum well width. Also, the *p*-GaN is grown at low temperature to avoid the disintegration of the InGaN quantum wells with high InN content. A redshift is observed for both the green and yellow LEDs upon decreasing the injection current at low current regime. In the case of the yellow LED, this shift is enough to push emission into the amber (601 nm). Five –nanometer thick silicon on insulator layer [Journal applied Physics 98, 106104 (2005)].

3. **“Dependence of ferromagnetic properties on carrier transfer at GaMnN/GaN:Mg interface**”

[Applied Physics Letters 85, 3809 (2004)].

F. E. Arkun, M. J. Reed, E. A. Berkman, and N. A. El-Masry, J. M. Zavada, M. L. Reed and S. M. Bedair

Abstract:

We report on the dependence of ferromagnetic properties of metalorganic chemical vapor deposition grown GaMnN films on carrier transfer across adjacent layers. We found that the magnetic properties of GaMnN, as a part of GaMnN/GaN:Mg heterostructures, depend on the thickness of both the GaMnN film and the adjacent GaN:Mg layer and on the presence of a wide band gap barrier at this interface. These results are explained based on the occupancy of the Mn energy band and how the occupancy can be altered due to carrier transfer at the GaMnN/GaN:Mg interfaces.

4. “Effect of doping on the magnetic properties of GaMnN: Fermi level engineering”.

M. J. Reed, F. E. Arkun, E. A. Berkman, and N. A. Elmasry, J. Zavada, M. O. Luen, M. L. Reed, and S. M. Bedair

[Appl. Phys. Letters 86, 1(2005)]

Abstract:

GaMnN dilute magnetic semiconductor samples, prepared by metalorganic chemical vapor deposition, are shown to exhibit ferromagnetism or even paramagnetism depending upon the type and concentration of extrinsic impurity present in the film.

In addition, GaMnN deposited using growth parameters normally yielding a nonferromagnetic film becomes strongly ferromagnetic with the addition of magnesium, an acceptor dopant. Based upon these observations, it seems that ferromagnetism in this material system depends on the relative position of the Mn energy band and the Fermi level within the GaMnN band gap. Only when the Fermi level closely coincides with the Mn-energy level is ferromagnetism achieved. By actively engineering the Fermi energy to be within or near the Mn energy band, room temperature ferromagnetism is realized.

5. "Magnetotransport properties of (AlGaN/GaN)/ (GaMnN) heterostructures at room temperature"

Amr Mahrous, M. O. Luen, A. Emara, E. A. Berkman, J. Zavada, S.M. Bedair and N. A. El-Masry.

[APPLIED PHYSICS LETTERS **90**, 252503 _2007].

Abstract:

Dilute magnetic semiconductor films _GaMnN_ are highly resistive, making transport measurements difficult to achieve. However, when GaMnN films are sandwiched between *p*-type doped AlGaN/GaN_ strained-layer superlattices, holes from the superlattice interact with the Mn3+/2+ ions and transport measurements were realized. The authors have found also that the ferromagnetic properties of GaMnN critically depend on the level of *p*-type doping in the superlattice. They report anomalous Hall effect measurements in this _AlGaN/GaN_:Mg/ _GaMnN_ multilayered structure.

The current results also demonstrate the role of carriers, especially holes, in mediating the ferromagnetic properties of GaMnN dilute magnetic semiconductor films.

6. "Development of Yellow and White LED's Using InGaN-based Multi-Quantum Well Structures"

P. T. Barletta[a], E. A. Berkman[a], A. M. Emara[b], M. J. Reed[a], N. A. El-Masry[a], and S. M. Bedair[b]

[ECS-Cancun meeting 2007]

Abstract:

In recent years, InGaN-based LED's emitting in the blue and green spectral regions have emerged into widespread use. However, due to fundamental material issues related to InGaN, achieving yellow and red emission from InGaN-based structures has presented a unique challenge. We have developed conditions for the MOCVD growth of a series of InGaN-based MQW devices that emit over a wide spectral range (420nm - 600nm). It has been found that the emission properties of these monochromatic devices depend critically on the growth rate, growth temperature, QW width, barrier growth conditions, and p-type capping layer growth conditions.

Additionally, we have demonstrated white electroluminescence through the proper mixing of complementary colors.

7. “Ferromagnetic GaMnN Films and Heterostructures (a Review).”

Nadia A El-Masry, Amr M. Mahros, and M. O. Luen

[MRS Spring meeting, symposium K. 2007]

Abstract:

We will review the growth of dilute magnetic semiconductors (DMS) showing ferromagnetic behavior above room temperature in our laboratory. Two approaches were used for doping III-Nitride films with transition metals. One approach used post growth solid state diffusion of the transition metal layer deposited by PLD on the MOCVD nitride films. The second approach used direct MOCVD growth of GaMnN films using
(EtCp2) Mn as the Mn-precursor. The Curie temperature of these films ranged from 270K to above 400K depending on the Mn concentration. Our experiments reveal a possible mechanism of the observed magnetic property in this material system. The ferromagnetic properties of Mn-doped III-nitride films are strongly related to the Fermi level position.
Si or Mg co-doping of ferromagnetic MnGaN films results in the suppression of the film's ferromagnetic behavior. High Si or Mg (1020 atoms/cc) doping results in the loss of the ferromagnetic behavior of the films. The ability to control the ferromagnetism is demonstrated where bringing the Fermi level to the Mn-energy level is required to achieve DMS-GaMnN. We have also found that charge transfer across ferromagnetic and non magnetic interfaces resulted in changes in the magnetic properties. Several heterostructures will demonstrate the validity of the above mechanism.